RESEARCH DEPARTMENT

The performance of an 18:1 zoom lens for the plumbicon format:

the P. Angénieux 18x27·5 E31 No.1213679

TECHNOLOGICAL REPORT No. PH-25

UDC 681.42.08:621.397.132 1968/48

THE BRITISH BROADCASTING CORPORATION
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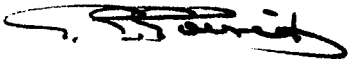

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THE PERFORMANCE OF AN 18 : 1 ZOOM LENS FOR THE PLUMBICON FORMAT: THE P. ANGENIEUX 18x27·5 E31 No. 1213679

SUMMARY

This report details the measured optical performance of the P. Angénieux 18×27·5 E31 lens, an 18 : 1 zoom lens specifically designed for use with the EMI type 2001 four-plumbicon colour camera.

The measurements reported upon are for the transmission, veiling glare index, vignetting and modulation transfer function at full and reduced apertures. The measured performance is used to obtain an assessment of the subjective quality of the image formed by the zoom lens. Comparison is made with a 10 : 1 zoom lens type currently in service, namely the P. Angénieux 10×18 J1.

1. INTRODUCTION

The particular zoom lens reported upon has been specifically designed for use with the EMI 2001 four-plumbicon colour camera. A variant of the lens, the 18×27·5 E11, is available for use with the Peto-Scott three-plumbicon colour camera, and the performance of the two variants is expected to be similar.

A brief specification of the lens is given below:

focal length range:	27·5 to 500 mm
maximum aperture:	f/2·0 to f/3·0 (according to focal length setting)
near working distance:	3 m (10 ft)
image format:	17·12 × 12·84 mm
weight:	16 kg. (35 lb)

The 18×27·5 E31 zoom lens has a larger focal length ratio than any zoom lens previously reported upon.[1] In order to minimise weight, dimensions and cost, the lens does not have a constant geometrical aperture over the entire zoom ratio. The maximum aperture of f/2·0 is maintained, at wide angle settings of the zoom lens, over a focal length ratio of about 11 : 1. The maximum available aperture at longer focal lengths decreases progressively with increase in focal length, giving at 500 mm a maximum aperture of f/3·0.

The test conditions differed from those used when testing the 10: 1 ratio zoom lenses previously reported upon.[1] The focus condition was obtained by the normal method of successive approximations, except that the focus was readjusted, off axis, at one third the image-field diagonal, to obtain the maximum modulation at 16·7 c/mm for each tested focal length setting.*

The test-object illuminant also differed from the tungsten-white source previously used. Measurements of modulation transfer function (m.t.f.) were made using a test object illuminated with wide-band green light whose emission spectrum, with the photomultiplier response, gave an overall characteristic similar to the photopic curve. It was considered that because the lens was designed specifically for use with a four-tube colour camera, measurements of m.t.f. obtained using a wide-band green illuminant would be closer to the results obtained in actual use.

2. MODULATION TRANSFER FUNCTION

Measurements of m.t.f. were made at eight focal-length settings, namely 27·5, 35, 50, 90, 150, 275, 375 and 500 mm. The test object was effectively located at infinity by means of a collimating lens.

The results obtained at the maximum aperture are shown in Figs. 1 to 7. The effect of stopping the lens down to f/2·8 over the major part of the zoom range is shown in Figs. 8 to 14. The detailed m.t.f. measurements given in Figs. 1 to 14 are summarized in Fig. 15, which shows the variation of the modulation transfer factor at 16·7 c/mm over the image format for various focal-length settings. Comparison of the modulation transfer factor, at full and reduced aperture, shows an improvement of between 15% to 20% over most of the focal length range when the aperture is reduced.

* For the plumbicon format of 21·4 mm diagonal, the spatial frequency of 16·7 c/mm corresponds to 5·5 MHz, the cut-off frequency of the 625-line television system.

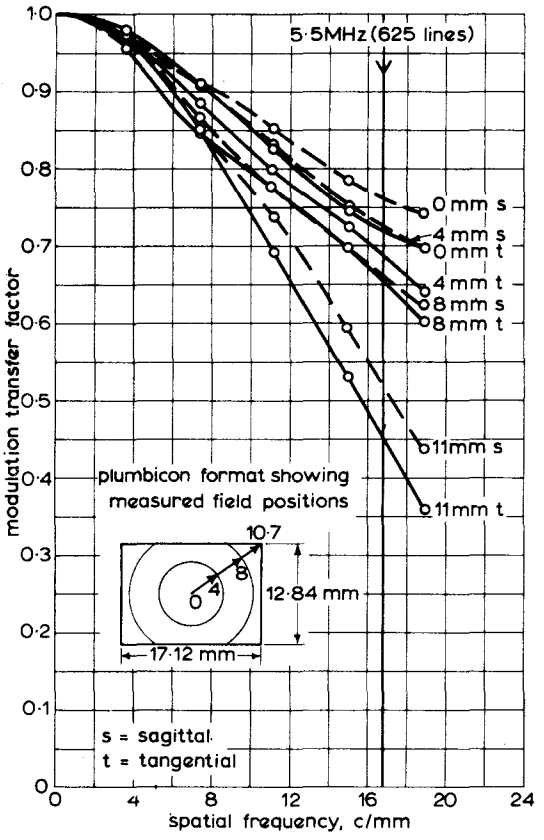

Fig. 1 - 27·5 mm focal length at f/2·0

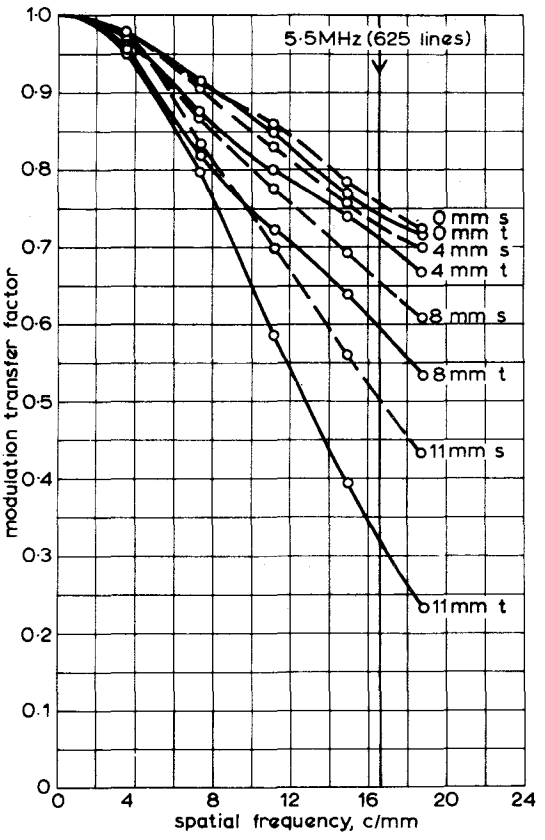

Fig. 2 - 35 mm focal length at f/2·0

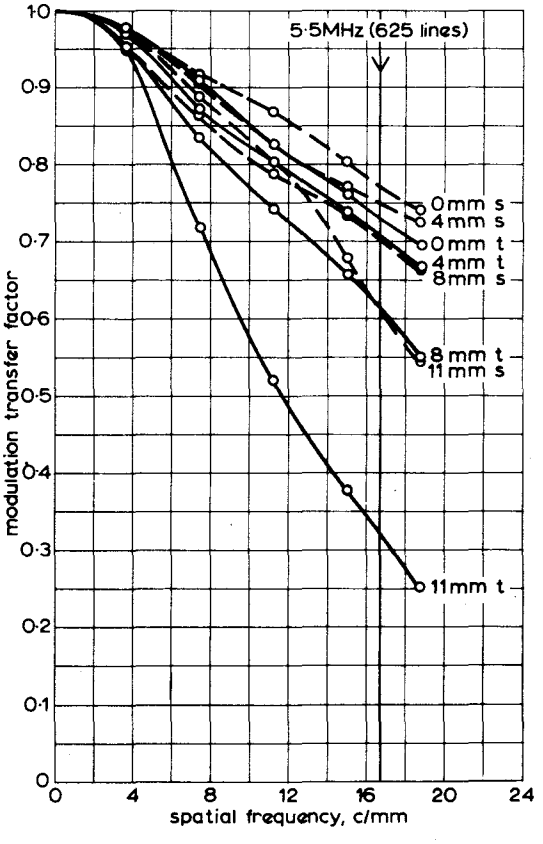

Fig. 3 - 50 mm focal length at f/2·0

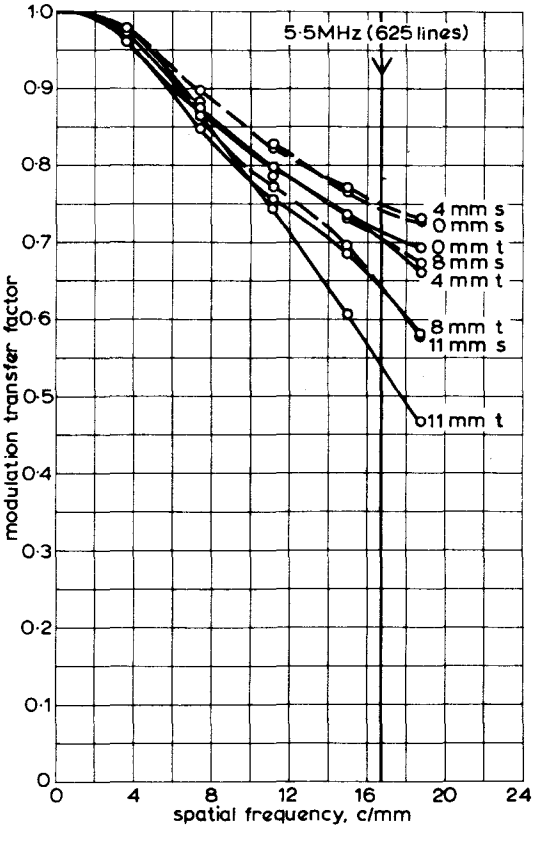

Fig. 4 - 90 mm focal length at f/2·0

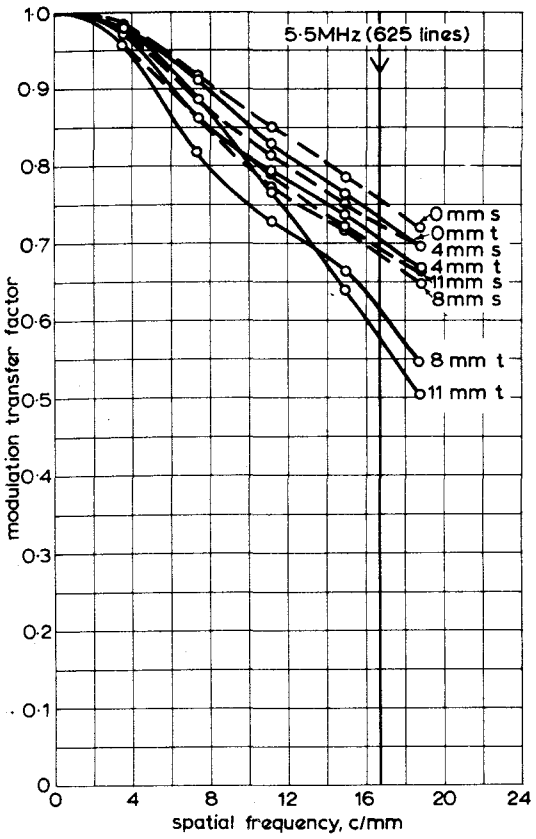

Fig. 5 - 150 mm focal length at f/2·0

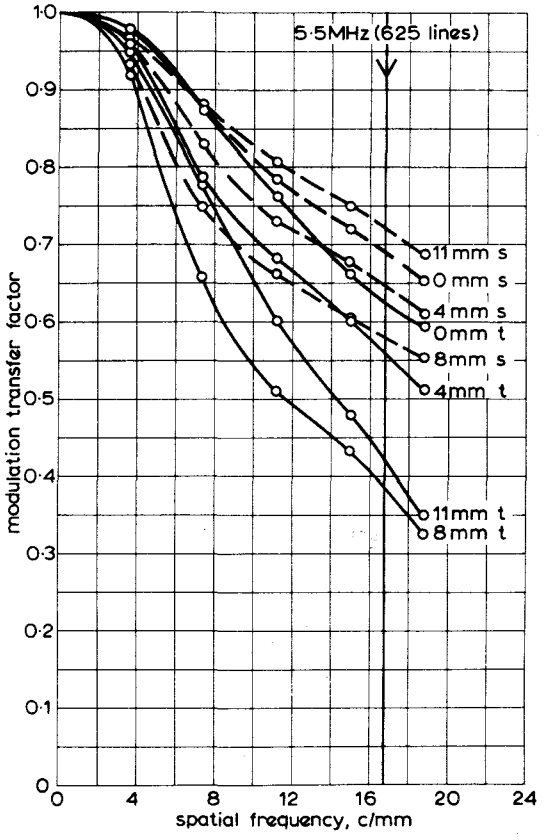

Fig. 6 - 275 mm focal length at f/2·0

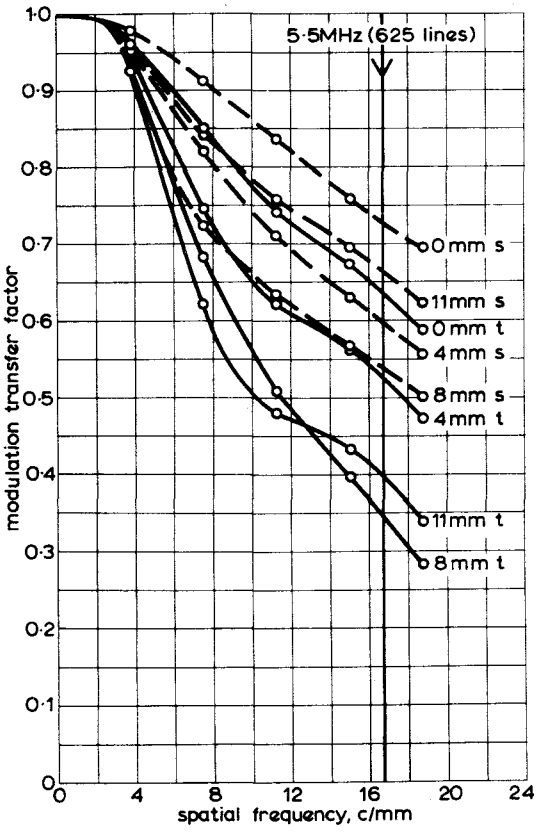

Fig. 7 - 375 mm focal length at f/2·0

Figs. 1 to 7 - Modulation transfer function at full aperture
test object at infinity
wide-band green light source
16·7 c/mm focus at 1/3 field diagonal

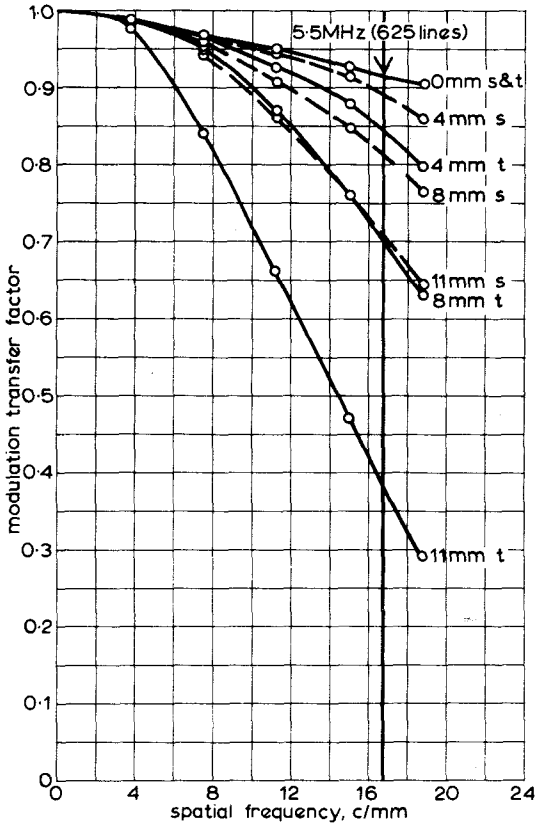

Fig. 8 - 27·5 mm focal length at f/2·8

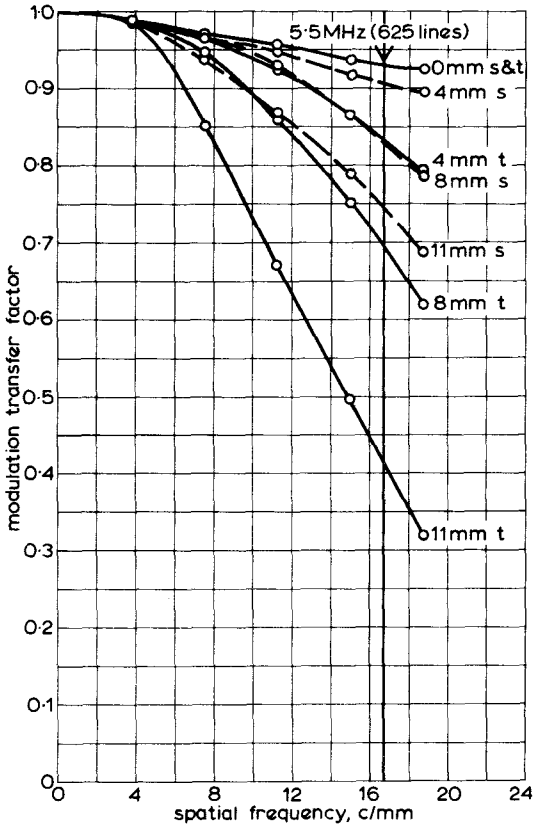

Fig. 9 - 35 mm focal length at f/2·8

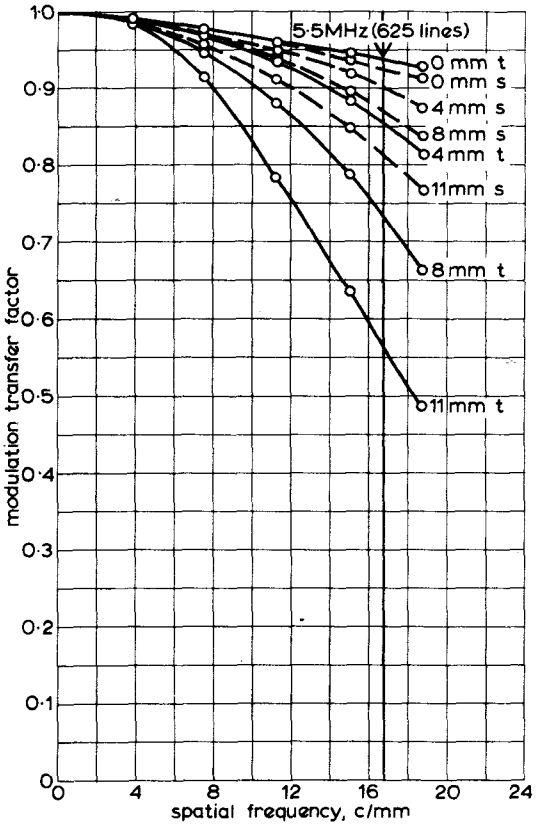

Fig. 10 - 50 mm focal length at f/2·8

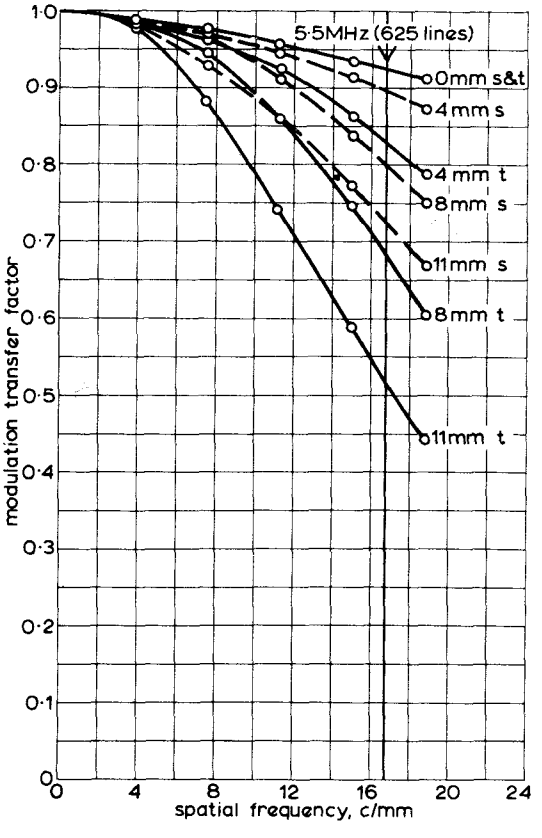

Fig. 11 - 90 mm focal length at f/2·8

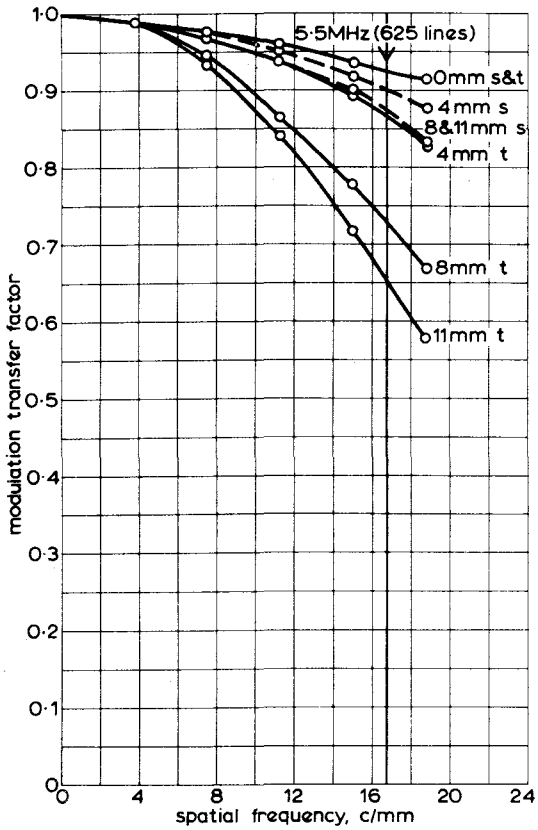

Fig. 12 - 150 mm focal length at f/2·8

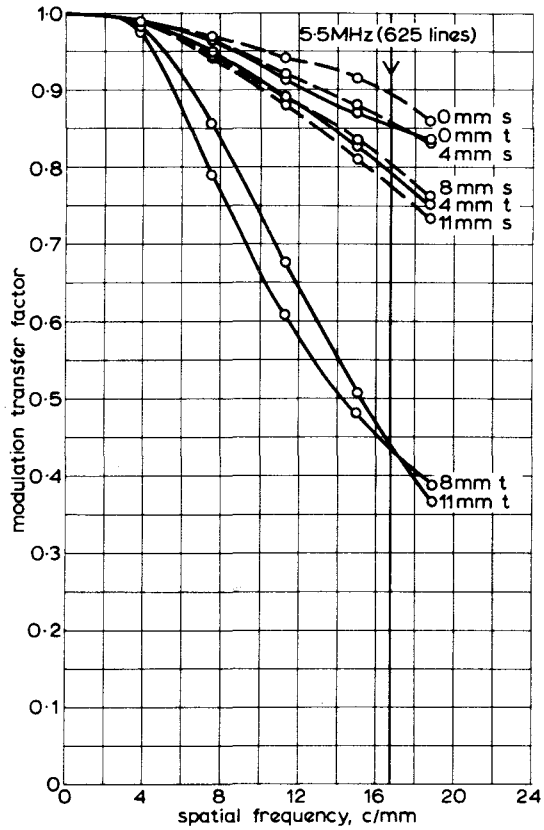

Fig. 13 - 275 mm focal length at f/2·8

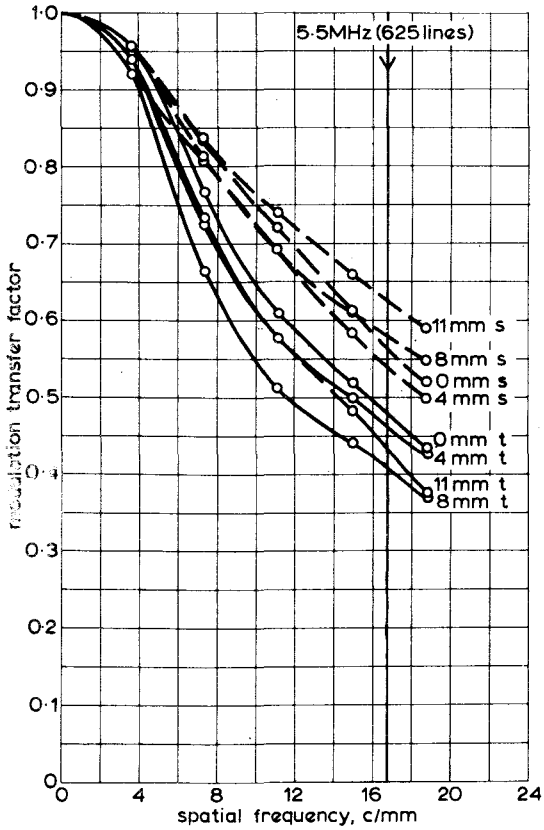

Fig. 14 - 500 mm focal length at f/3·0

Figs. 8 to 14 - Modulation transfer function at reduced aperture
test object at infinity
wide-band green light source
16·7 c/mm focus at 1/3 field diagonal

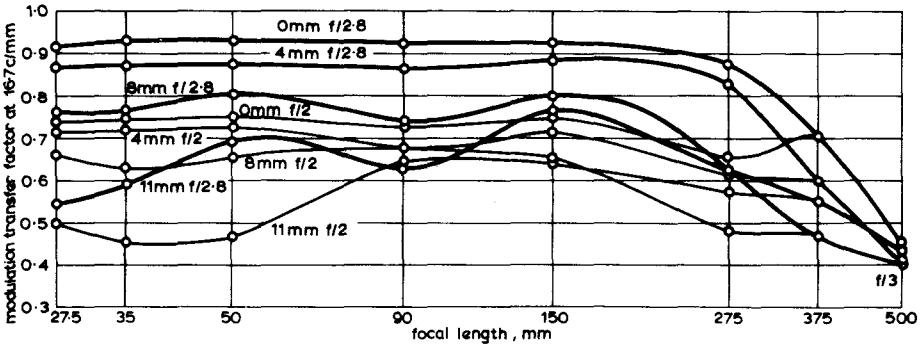

Fig. 15 - Modulation transfer factor at 16·7 c/mm for full and reduced apertures, for image field positions of 0, 4, 8 and 11 mm off axis

3. VIGNETTING

The manufacturer's published literature[2] on the type 18×27·5 E31 lens includes the vignetting characteristics. Measurement of image vignetting was carried out only in sufficient detail to check agreement with the manufacturer's data. The measured vignetting characteristic for three focal lengths is shown in Fig. 16. The measured results are acceptable and in good agreement with the manufacturer's data.

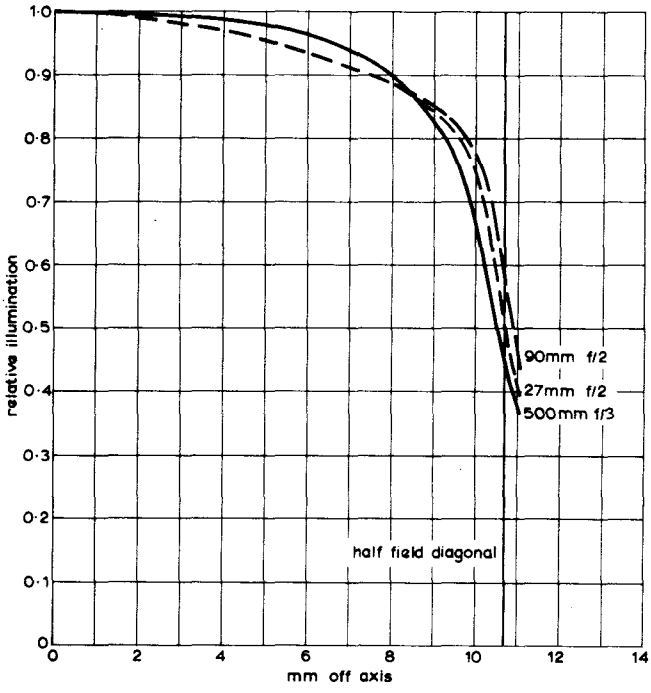

Fig. 16 - Vignetting characteristics at full aperture. 18×27·5 E31 lens

4. TRANSMISSION AND VEILING GLARE INDEX

The axial transmission of the lens to white and tri-colour red, green and blue illumination is given in Table 1.

TABLE 1

Axial Light Transmission

Illumination	Red	Green	Blue	Tungsten
Percentage Transmission	73·0	75·5	60	71·5

The transmission of the lens is typical of the Angénieux range of zoom lenses.

The maximum veiling glare index[3] of the lens for white, red, green and blue incident illumination is shown below in Table 2.

TABLE 2

Maximum Veiling Glare Index at Full Aperture

Focal length mm	Colour of scene illumination			
	White	Red	Green	Blue
90	0·85	0·8	0·85	1·1
150	0·8	0·8	0·8	1·05
250	0·75	0·7	0·7	0·9
500	0·75	0·7	0·7	0·9

Measurements at focal lengths giving larger field angles than that corresponding to 90 mm focal length were not made. The very large object field required with a minimum test-object distance of 3 m was not available.

The veiling glare index of the lens at the measured focal length settings is excellent.

5. ENTRANCE AND EXIT PUPIL LOCATION

The entrance pupil of a zoom lens varies in location with both focal length and focus setting.

The entrance pupil location is of interest because of the effect on image perspective and, for the lens type 18×27·5 E31, varies between the limits shown in Table 3. The measurements are taken from the front element towards the rear of the lens.

TABLE 3

Entrance Pupil Location

Focus Position	Narrow Angle	Wide Angle
∞	1·47 m	120 mm
3 m (10 ft)	4 m	240 mm

The exit pupil is of particular interest with regard to the effect on colour-camera dichroic tilt.[4] The exit pupil of most zoom lenses is independent of zoom and focus settings and, for the 18×27·5 E31 lens, is located 110 mm to the rear of the image plane. This is rather close to the image from the point of view of dichroic tilt.

6. SUBJECTIVE ASSESSMENT

It is possible to relate both the measured modulation transfer function and the vignetting to the subjective assessment of the image quality over the whole image format.[5] The unit of image quality is the 'limen', defined as the change in image quality which half of any group of observers will just perceive.

The subjective assessment of the 18×27·5 E31 lens at full and reduced aperture is shown in Fig. 17. The image-sharpness impairment at full aperture is less than 1·5 limen over an 8 : 1 zoom ratio; at reduced aperture the sharpness is excellent, the impairment being below 1 limen over a 10 : 1 range and about 0·5 limen over an 8 : 1 zoom range. The effect of vignetting is not shown, but at full aperture the effect of vignetting is less than 0·5 limen.

7. COMPARISON WITH 10×18 J1 ZOOM LENS

A P. Angénieux 10 : 1 zoom lens currently used with colour cameras is the type 10×18 J1; this lens has a focal length range of 18 to 180 mm, a maximum aperture of f/2·2 and a near working distance of 1 m.

Direct comparison between the 18×27·5 E31 and 10×18 J1 zoom lenses is difficult because of the different test conditions used. On the basis of some unpublished investigations on the differences of m.t.f. measurements with tungsten-white as compared with broad-band green illumination, an approximate comparison may be made by assuming that a zoom lens tested with broad-band green light is characterised by an image sharpness of between 0·5 and 1 limen better than when it is tested with white light.

Based upon this assumption, Fig. 18 compares the image-sharpness qualities of the 18×27·5 E31 and 10×18 J1 lenses at full and reduced apertures. It will be seen that the 18×27·5 E31 lens has a performance at least as good as the 10×18 J1 lens. The 18×27·5 E31 lens has the added advantage of an extended zoom range and a slightly larger maximum aperture.

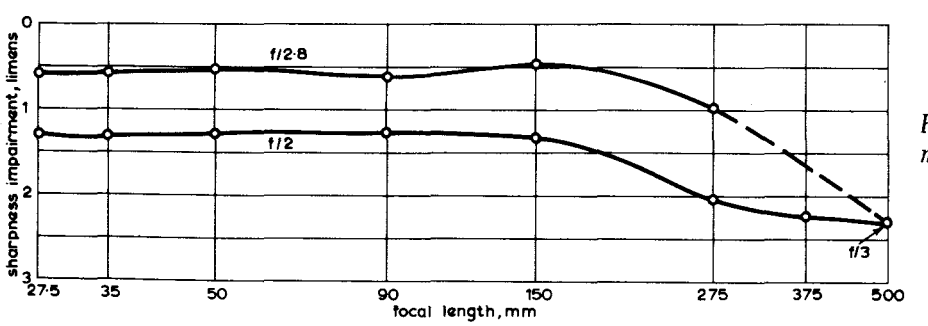

Fig. 17 - Image quality assessment for full and reduced apertures. 18×27·5 E31 lens

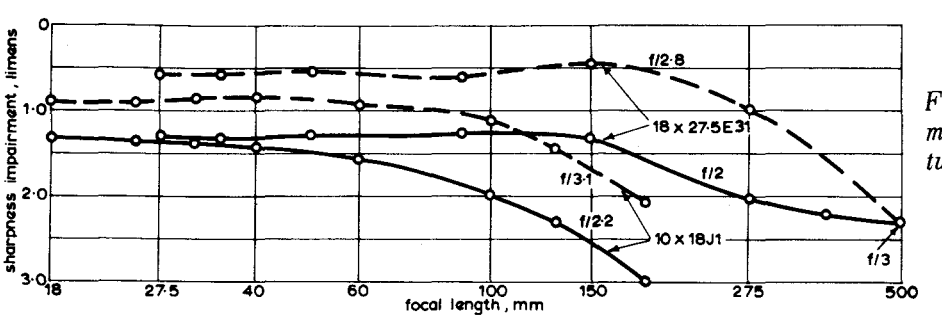

Fig. 18 - Image quality assessment for full and reduced apertures. Lens types 18×27·5 E31 and 10×18 J1

8. CONCLUSION

The sharpness of the image formed by the 18×27·5 E31 zoom lens is good at full aperture and excellent at reduced aperture. The transmission factor and veiling glare indices are excellent for a zoom lens. The effect of vignetting on the image quality is small at full aperture and negligible at all other apertures.

The 18×27·5 E31 zoom lens, compared with the 10 : 1 lenses in current use, gives an extended zoom range without significant deterioration of image quality over at least a 10 : 1 zoom ratio.

9. REFERENCES

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